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FULL PAPER

Technological Use of Flour Obtained from the Byproducts of Passion Fruit Albedo and the Residue of the Extraction of the Star Fruit Juice in the Formulation of Cereal Bars

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Abstract:

The fruits industrialization process for the production of new food products generates a significant number of agroindustrial residues. The use of these residues in the formulation of new products such as cereal bars adds nutritional value to foods and helps in the reduction of environmental impacts. The objective of this work was to produce flours from the star fruit residue and the passion fruit albedo, to attain the physicochemical characterization and to elaborate three cereal bars formulations with variation in the contents of the flour produced. The results indicate that the star fruit and the passion fruit's albedo can be considered as an alternative source of nutrients, ranging from energy supplementation to its insertion in derived products due to its technological characteristics. The developed cereal bars were widely accepted, and most evaluators reported that they would buy such products.

Keywords: agroindustrial residues; healthy eating; nutritional value; sensory analyses

1. Introduction

Fruticulture is a sector of great importance in the world economy, generating income, jobs and rural development. The use of fruits as a raw material in the formulation of juices, jellies, jams and other products, generates a surplus, which applied in other products contributes to a lower environmental impact that would be caused by the food industry [1]. In the diet, fruits are a source of essential elements and constitute the necessary minerals for human consumption [2].

It is essential that humans have a healthy and nutrient-rich diet. Some nutrients make up the parts of the fruits that are neglected by the industry, such as: peelings, stalks and leaves. And the reuse of these residues in the development of new products, in addition to reducing the environmental impact, improves men's nutritional quality [2].

The passion fruit, originating in Tropical America, is a sub-woody climbing plant, with high vegetative vigor and it belongs to the family order Passiflorales [3]. The world production is accounted in 364 thousand tons, obtaining a yield of 7.5 t/ha. Brazil is among the main producing countries, with 90% of the world's production and it stands out with a production of 330.8 thousand tons, with yield of 9.9 t/ha in an estimated area of 33.4 thousand hectares [4].

The fruit can be consumed *in natura* or industrialized. Passion fruit's derivate products are highly appreciated by consumers, among them are the concentrated juice and pulp, nectars, soft drinks, concentrates for soft drinks, syrups, ice-creams and jellies [3].

In the industrialization process of the passion

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fruit's derivatives, the fruit is crushed, generating tons of residues such as peels and seeds, which are currently destined for the formulation of new by-products that furnish human feeding or are used for supplementation in the animal's food. As this number is very expressive at the environmental level, it is of general interest to add economic, scientific and technological value to these by-products [4].

These agroindustrial residues have been the object of studies aiming their functional properties, mainly those related to the content and type of fibers. The peel represents 52% of the fruit's mass composition, and since they are functional characteristics and properties, they are no longer considered as waste and are used in the elaboration of new food by-products. High fiber, pectin and carbohydrate contents are present in the composition [5]. Another residue from the industrialization of passion fruit is the mesocarp (albedo), which presents high levels of pectin, niacin (vitamin B3), iron, calcium and phosphorus [6].

In human health, niacin, besides acting in the growth and production of hormones, also prevents gastrointestinal problems. Minerals help prevent anemia (iron), bone growth and strengthening (calcium), and cell formation. The fibers present in the shell of the passion fruit are a soluble type, in other words, benefical to the human organism, pectins and mucilages that help in the prevention of diseases, unlike the insoluble fibers that can impair the absorption of iron. The increase of dietary fiber in the human diet helps to prevent cardiovascular diseases, gastrointestinal diseases, cervical cancer, hyperlipidemic diseases, diabetes and obesity, among other benefits [6].

The star fruit tree (*Averrhoa carambola* L., Oxalidaceae) is native to Asia and typical of the tropical regions of both hemispheres. It is considered an exotic fruit due to its star shape and its cultivation is practiced by almost all of Brazil territory, except in cold regions prone to frost. This tree presents fast development, high productivity, low cultivation requirement, producing sweet varieties and fruits with unique appearance and flavor. Brazil is the third largest producer, and such tree was introduced in this country around the year of 1817, being used in home treatments to stimulate appetite, control diarrhea and fever. The cultivation of this fruit in Brazil is predominant in domestic orchards with an estimated production of 3,000 tons/year [7].

In the star fruit composition there are vitamins, minerals, fibers and essential compounds for men's diet. It is a fruit of great production, but the lack of commercialization and the easy deterioration are predominant factors that cause considerable losses of the food [8].

The high content of free water present in the fruits, besides making the food very perishable, is also the determining factor in the conservation and in product time of supply. In contrast, food technology relies on conservation methods such as freezing and drying, increases lifespan, makes the food more stable and makes it last longer in storage. The drying preservation method stands out against the freezing, because it is a process that assigns many advantages, among which there are the easiness in food conservation, preservation against enzymatic and oxidative degradation, product weight loss, the reduction in energy costs, since, refrigeration is not required and the availability of the product at any time of the year [8].

The constant search for a healthier life and the change in the consumers' eating habits caused the industries to focus on the development of new food products, which, coupled with economic factors such as the use of by-products, led to the emergence of cereal bars, which have high nutritional value. The first cereal bars were sold in the United Kingdom in the 1980s, but the United States is currently the world's largest consumer of cereals, trading at about $ 2.9 billion a year [9].

Cereal bars are an excellent choice for people who want a healthy, low calorie diet or yet, a meal supplement. They are foods made from the compaction of dehydrated fruits and cereals, such as, oats, wheat, soy, corn and rice, among others. The cereals present in their composition are sources of carbohydrates that provide energy for physical and mental activity, vitamins and minerals essential for human health. In the market there are four types of cereal bars, among them are fibrous, dietary, energetic and proteins [10].

The fibrous bars have high sugar and fiber levels and also provide a considerable level of energy. Its consumption is recommended after the practice of physical exercises. The diets are recommended for people with diabetes or those who want a diet with low energy levels, since they do not include sugars and have fewer calories and fats. Since they are not efficient foods in the replacement of high amounts of energy, it is recommended that it be consumed before the practice of physical exercises. The energetic cereal bars present smaller amounts of fibers and so are easily absorbed. Since these bars have higher amounts of calories, they are consumed during or after physical exercises. Proteins, on the other hand, contain less lipids and higher amounts of protein, therefore, the ideal is to be consumed after exercises, aiming at the aid of mass gain and, like the energetics, they are not recommended for sedentary people [10].

Aiming to contribute with a lowest environmental impact and to develop nutritious food for human health, this work had the objective to make use of the agroindustrial residues of the star fruit and passion fruit (mesocarp) to obtain flour, and the incorporation of them as ingredients in the formulation of three cereal bars

2. Material and Methods

The fruits of passion fruit used in this work were obtained from the Federal Technological University of Paraná - Dois Vizinhos Campus and the star fruit originated from the city of Frederico Westphalen, Rio Grande do Sul. Initially fruits were hygienized in sodium hypochlorite solution (100 ppm) for 10 min, then washed in running water (2 ppm chlorine). The albedo was used to obtain the passion fruit flour, and for the star fruit flour the juice extraction residue was used. The raw material was submitted to oven drying with air circulation (PARDAL) at 338 K until it reached constant weight. The dehydrated residue was ground in an industrial blender (METVISA) for 5 minutes.

The physicochemical analyzes were carried out at the Food Laboratory of the Federal Technological University of Paraná - Pato Branco Campus. All analyzes were performed in triplicates. The moisture content was determined in a conventional oven, at 378 K for 24 hours or until constant weight, quantified in a semi-analytical balance of 0.001 g precision. The mineral residue was also determined by gravimetry, by carbonization in electric stove and incineration in a muffle furnace at 823 K until clear ash was obtained according to the methodology of the Adolfo Lutz Institute (1985) [11]. The lipids were quantified by extraction in Soxhlet apparatus, using petroleum ether as a solvent described in the methodology of the Adolfo Lutz Institute (2008) [11]. For the determination of the protein content, the KJEDAHL method and the factor 6.5 in the conversion to protein nitrogen were used, according to the methodology described by Tedesco et al. (1995) [12]. The analysis of water activity was determined with the Water Activity equipment (NOVASINA LAB MASTER). The amount of carbohydrate was determined from the difference between the initial mass of the sample (100 g) and the total mass of proteins, lipids, mineral residue and moisture.

The formulations of the cereal bars were composed of rolled oats, rice flakes, grated coconut, brown sugar, crystal sugar, star fruit flour, passion fruit flour, honey, vegetable oil, star fruit juice and passion fruit juice. Formulation adapteded from Gomes et al (2010), where it was added star fruit flour and the glucose syrup were replaced by crystal sugar and the passion fruit pulp by passion and star fruit juice. The dried ingredients were weighted, roasted for five minutes in an electric oven (FISCHER) and added to the syrup prepared from the dissolution of crystal sugar, brown sugar, vegetable oil, honey and fruit juice under bland heating. The formulation was further homogenized under heating for a further two minutes, and then the mass was deposited on a plain stainless steel form and rolled with baking roller, to an average thickness of 1 cm. Then, the bar was cut with a steel knife, obtaining bars with a standard size of 3.0 x 2.0 x 1.0 cm and average weight of 3 g. The proportion of flours used in the present study varied according to the proportions presented in Table 1.

The sensory analysis was applied in the laboratory of the Federal Technological University of Paraná – Pato Branco Campus, to 50 male and female judges, potential untrained consumers between the ages of 15 and 40 years. Each taster initially received a product evaluation card and then a single sample for each formulation in disposable cups, encoded with randomly chosen three-digit numbers. In addition to evaluating the attributes of color, taste, odor, texture and overall impression, the bars were evaluated using a hedonic scale of nine points (1 = "I greatly disliked", 9 = "I liked it a lot"). The bars were also evaluated in a buying intention hedoic scale of 5 points (1 = "certainly would not buy", 5 = "would certainly buy").

Table 1. Cereal bars formulation with star fruit flour and passion fruit flour.

Ingredients	Formulation (%)		
	F1	F2	F3
Rolled Oats	14.00	14.00	14.00
Rice flakes	14.00	14.00	14.00
Flour (star fruit)	6.00	9.00	3.00
Flour (passion fruit)	6.00	3.00	9.00
Grated coconut	5.00	5.00	5.00
Crystal sugar	25.00	25.00	25.00
Brown sugar	12.50	12.50	12.50
Plebeia's honey	9.00	9.00	9.00
Vegetal oil	3.50	3.50	3.50
Star fruit juice	2.50	3.75	1.25
Passion fruit juice	2.50	1.25	3.75

F1: 50% passion fruit flour 50% star fruit flour; **F2:** 25% passion fruit flour 75% star fruit flour; **F3:** 25% star fruit flour 75% passion fruit flour.

3. Results and Discussion

The results of the physico-chemical characterization and Water Activity of the passion fruit albedo flour can be observed in Table 2.

Table 2. Physical and physical-chemical characterization and passion fruit albedo at a 338.15 K temperature

Parameters	
Moisture (%)	7.44±0.28
Ashes (%)	8.83±0.00
Proteins (%)	11.39±0.00
Lipids (%)	0.73±0.07
Carbohydrates (%) *	71.61±0.20
Water Activity	0.42±0.00

*Obtained by difference

The passion fruit albedo flour presented low moisture content and water activity (Table 2), which proves that the drying of the albedo flour was performed correctly, because low levels of water in the flour represent protection against any microbiological alteration. As for bacterial growth, water activity should be between 0.6 and 0.9 [13]. As for ash, the average content found in this research was 8.83% under the drying conditions of 338 K. In studies with different conditions than those used in this work, lower levels for ashes were determined by Santana et al. (2011) [14] when drying the passion fruit peel flour at a temperature of 343 K, obtaining an ash content of 3.37%, however, the authors Ferreira et al. (2016) [15] observed a content equal to 5,11% for the passion fruit albedo flour. The value found for proteins was lower than those reported by Santana et al. (2011) [14] and Ferreira et al. (2016) [15], 2.65% for passion fruit peel flour and 5.47% for passion fruit albedo flour, respectively. Both studies were conducted at a temperature of 343 K. It was also found a lower lipid content than Souza; Ferreira; Vieira (2008) [16] for passion fruit peel flour (1.64%). The carbohydrate content found in the flour of this present study was lower than 79.39%, obtained by CAZARIN et al. (2014) [17] for the dried passion fruit peel flour at 323 K.

The results of the physical-chemical characterization and Water Activity of the flour obtained from the star fruit juice residue can be observed in Table 3.

Table 3. Physical and physical-chemical characterization of star fruit juice residue flour at a 338.15 K temperature.

Parameters	
Moisture (%)	9.39±1.11
Ashes (%)	2.81±0.18
Proteins (%)	7.97±0.00
Lipids (%)	0.90±0.07
Carbohydrates (%) *	78.93±1.35
Water Activity	0.52±0.00

* Obtained by difference

The moisture content of 9.39% obtained after drying (338.15 K) is in accordance with Ministry of Health Ordinance No. 354/96 which establishes a maximum moisture content of 15% for flours [18]. The moisture content found in this research was 9.39% under the drying conditions of 338 K. Lower levels were determined by Borges; Perreira; Lucena (2009) [19]. This difference is due to different conditions, as well as the drying temperature which was 343 K and because it was about dehydrated green banana flour. The authors Rodrigues et al. (2011) [20] when studying the *Smallanthus sonchifolius* potato flour in the drying condition of 328 K obtained a content equal to 6.09%. The flour had ash content equal to 2.81%, which represented good mineral content. Ribeiro (2008) [21] studied the *Smallanthus sonchifolius* potato pulp flour and obtained ash content equal to 2.88% and for the peel flour he found 6.81% dehydrated at 328 K. The value found for proteins was higher than those reported by Borges; Perreira; Lucena (2009) [19] and Ribeiro (2008) [21], 4.50% for green banana flour and 4.33% for pineapple peel flour, respectively. The flour under study presented low lipid content, as is expected for most products of plant origin. The authors Rodrigues et al. (2011) [20] determined lipid content of 0.15% for dehydrated *Smallanthus sonchifolius* potato flour, while Novais and Zuniga (2013) [22] found 1.01% for pineapple peel flour, both under drying at 343 K. The water activity content found in the present study is within the microbiologically safe limits. The authors Silva et al. (2012) [23] found superior content equal to 0.6 for the dehydrated *Malpighia emarginata* known as acerola (a fruit from the cherry family, Central and South American ative) residue flour at 333 K. Researchers Novais and Zuniga (2013) [22] studied the pineapple peel flour in the drying condition of 343 K and found a carbohydrate content equal to 60.61%, which was lower than that of the study in question. It weren't found on consulted literature works with star fruit flour, therefore it was used papers with another plant originated foods flour.

The group of sensory analysis evaluators was composed of 70% females and 30% males, and they were classified according to their age group, having a percentage of 38% between 15-20 years, 48% between 21-25 years, 12 % between 26-30 years and 2% between 31-40 years.

Analyzing the results histogram obtained regarding the cereal bars acceptance values frequencies by the testers expressed in the values of the hedonic scale for color, taste, odor, texture and overall impression (Figure 1), it is observed that in general all the attributes presented high percentages in the hedonic scale in the region of most acceptance of the graphs (between "I liked it lightly" and "I liked it very much", grades between 6 and 9) and low percentages in the area of rejection of the graphs (between "I disliked very much" and "neither liked nor disliked") thus indicating good sensory acceptance.

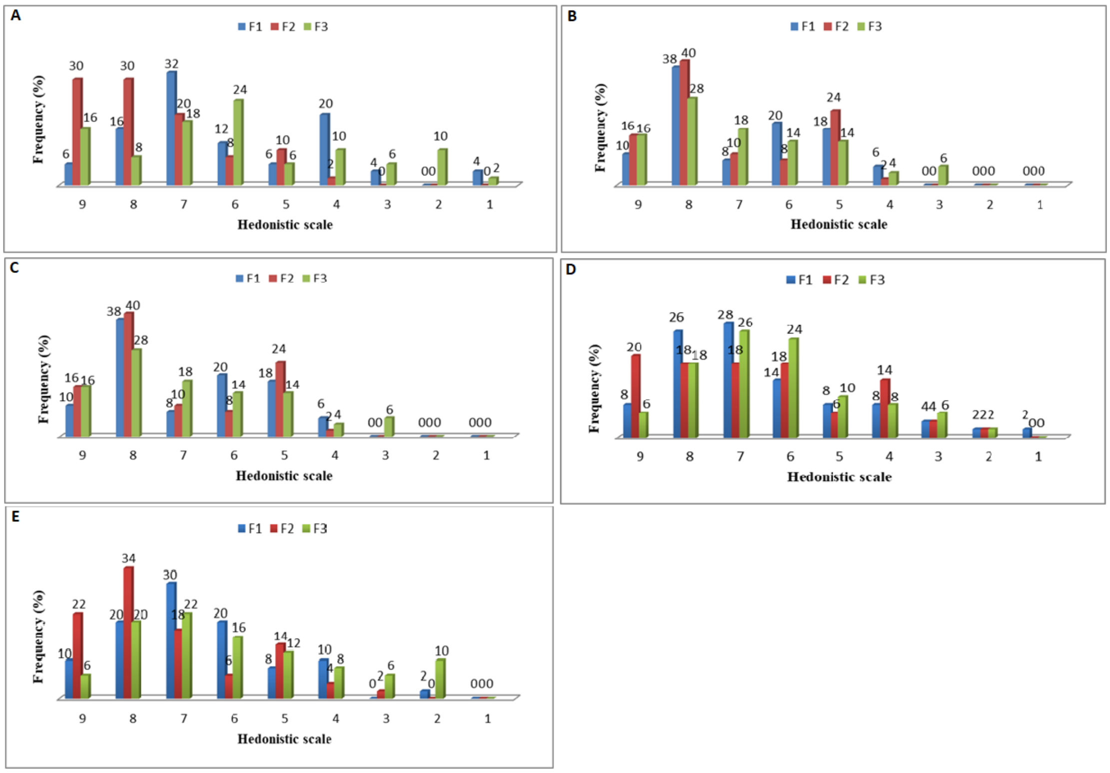

Figure 1. Histograms of sensorial analysis results of the three formulations of cereal bars, related to hedonic values of the atributes color (A), flavor (B), odor (C), texture (D) e overall impression (E) (9= I liked it very much and 1= I disliked it very much). F1: 50 % passion fruit flour 50% star fruit flour; F2: 25 % passion fruit flour 75 % star fruit flour; F3: 25 % star fruit flour 75 % passion fruit flour.

The judges pointed to formulation one (F1) as the best color cereal bar (Figure 1A) totalizing 90% of frequency. In relation to the flavor attribute (Figure 1B), formulation two (F2) stood out in relation to the others with 88% acceptance. In the evaluation of the odor attribute (Figure 1C) formulations one (F1) and three (F3) stood out with 76% of frequency. About the texture attribute (Figure 1D), it is noted that 76% of the judges chose formulation one (F1) as the most preferred. Regarding the overall impression (Figure 1E) the formulation one (F1) obtained greater acceptance totaling 80% of frequency.

In addition to the sensory analysis, a test of intent to purchase the elaborated products was performed with the same tasters. In this evaluation (Figure 2) positive results were obtained, where formulations one (F1) and two (F2) stood out in the research. It can be seen that commercialization of cereal bars is possible both in formulation one (F1) and formulation two (F2), since the intention of purchase was concentrated on "certainly buy" and "possibly buy", totalizing 50% for the cereal bar with equal parts of the flour and 62% for the bar with higher concentration of the carambola flour, showing good acceptance of these two formulations. However, formulation two (F2) accounted for 16% of the testers in the "certainly would not buy" and "possibly would not buy" region, showing that despite formulation one (F1) had good acceptance, formulation two (F2) stood out over the formulation one (F1).

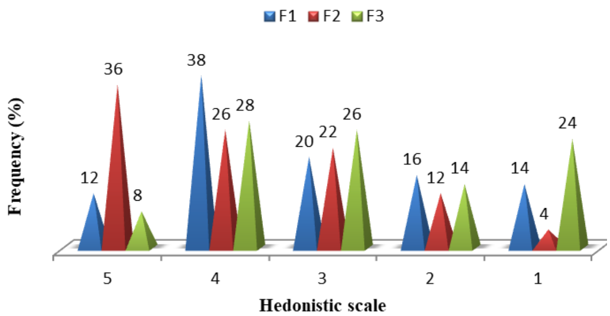

Figure 2. Histogram of sensorial analisys results of the five formulations of cereal bars, in relation to the frequency of hedonic values attributed to buying intention (5= Would certainly buy e 1= Would certainly not buy). F1: 50 % passion fruit flour 50% star fruit flour; F2: 25 % passion fruit flour 75 % star fruit flour; F3: 25 % star fruit flour 75 % passion fruit flour.

4. Conclusions

The obtained results allow us to conclude that the passion fruit albedo flour and the extraction of the star fruit juice can be used as an ingredient in the formulation of cereal bars, by aggregating the protein value to the product and by the acceptance indicated by the sensorial tests. From the results analysis of the sensorial quality attributes and intention to purchase it, can be concluded that formulations one (F1) and two (F2) indicate good sensory acceptance in relation to the others, since they present high percentages in the region of greater acceptance of the hedonic scale. These results demonstrate that the developed product has great consumption potential. The cereal bars made with the flours produced from the agro-industrial by-products offer a new variation of this type of product in the market, constituting an alternative of healthy and differentiated foods.

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